

LITTLE LASER BIG SCIENCE

*A universally useful tool
pioneered and perfected at Los Alamos
is exploring other planets
and improving life on this one.*



Mars's Mount Sharp, the source of new geological LIBS data that suggest Mars may have once been flush with both liquid water and atmospheric oxygen.

CREDIT: NASA/JPL/MSSS

SOME TOOLS, LIKE A CROSSHEAD SCREWDRIVER, are only good at the task for which they were invented. Others, however, like a flathead screwdriver, are often useful for tasks beyond their original one. Over 30 years ago, scientists at Los Alamos developed a tool for watershed preservation that detects and measures naturally occurring toxic metals in soil. That tool is now being used in various scientific endeavors, from exploring Mars's chemical makeup to protecting precious pipelines.

Laser-induced breakdown spectroscopy (LIBS) is a technique that reveals the presence and concentration of elements in a sample. A small but powerful laser is used to vaporize a minuscule amount of material from the surface of the sample, creating a tiny plasma that contains energetically excited atoms. As the plasma cools, the atoms emit light at wavelengths characteristic of their elements and a spectrometer measures the light emissions, which are then used to calculate the concentration of each type of atom in the sample. LIBS is handy because it's virtually nondestructive, portable, adaptable, rapid, remote (can measure a sample from a distance), and affordable—which is why it can be used in so many environments, including other worlds.

The latest news from Mars came via ChemCam, a Los Alamos LIBS analyzer aboard the rover *Curiosity*. Deposits of manganese oxide and strong silica enrichment were discovered, suggesting that liquid water may have been present much later, and that there may have been more oxygen in the planet's past, than was previously thought.

"Manganese deposits only formed on Earth after the rise of photosynthesis, when the atmosphere was flooded with free oxygen produced by photosynthetic microbes," explains Los Alamos planetary scientist Nina Lanza. The manganese deposits on Mars suggest that Mars too had significant amounts of oxygen in its atmosphere at some point, although the source of that oxygen is still unclear. One hypothesis is microbes. Another is that the oxygen came from water molecules being split by ionizing radiation, resulting in the lighter hydrogen atoms escaping Mars's atmosphere and the heavier oxygen atoms staying behind.

Laser-induced breakdown spectroscopy, or LIBS, is a technique to reveal what elements are present in a sample. A powerful laser is used in quick, successive pulses to ablate nanograms of material from the sample's surface, creating a micro-plasma in which energetically excited atoms dissociate into ions and electrons. As the excited atoms and ions lose their excess energy, they emit characteristic wavelengths of light, and a spectrometer is used to resolve the wavelengths and measure the intensity of those emissions to determine which elements are present in the sample and in what relative proportions.

The discovery of rocks strongly enriched with silica led to two more discoveries. First, the detection of tridymite, a silicate mineral that is rare on Earth, was the first-ever evidence of Martian silicic volcanic activity, which is a specific type of explosive volcanism.

"The second discovery," Lanza's colleague astrogeologist Jens Frydenvang explains, "came from where, within Mars's bedrock, we found high-silica. It was along the fractures, which suggests that liquid water was present much later than previously thought—extending the time period in which Mars could have supported microbial life."

As successful as ChemCam has been, Los Alamos scientists are eager for data from the next rover, scheduled to launch in 2020. Its updated Los Alamos instrument dovetails LIBS with Raman spectroscopy, a technique that identifies specific molecules, complementing the elemental analysis of LIBS.

Back here on Earth, LIBS is proving to be quite useful for national security in several arenas. LIBS can be used by International Atomic Energy Agency inspectors to rapidly detect the presence of nuclear material in a variety of samples, with little-to-no sample preparation. Because LIBS can distinguish between different isotopes of the same element,

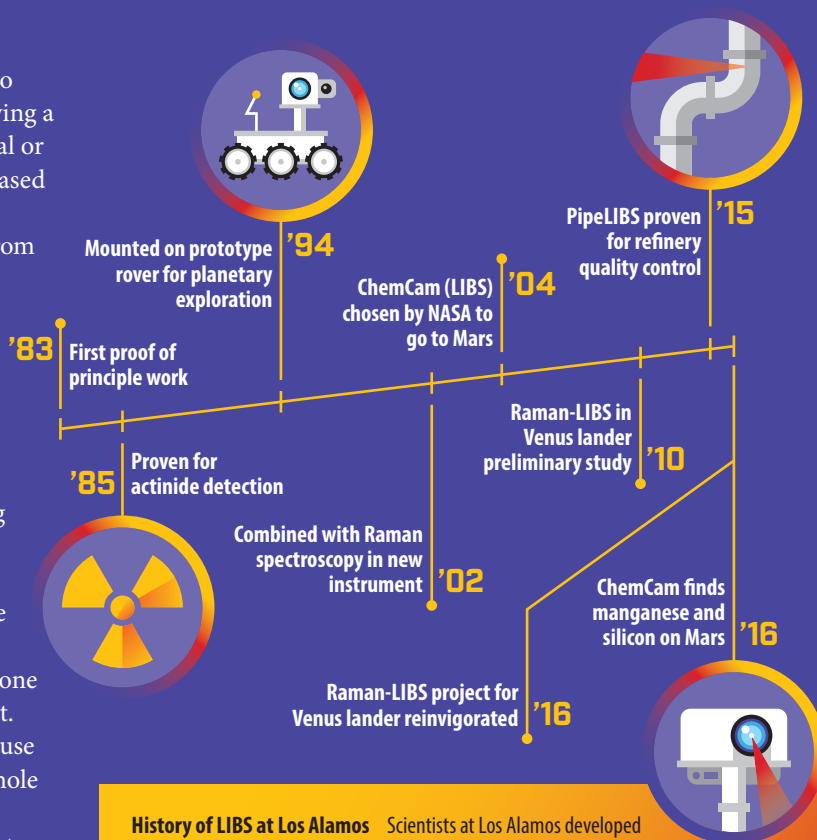
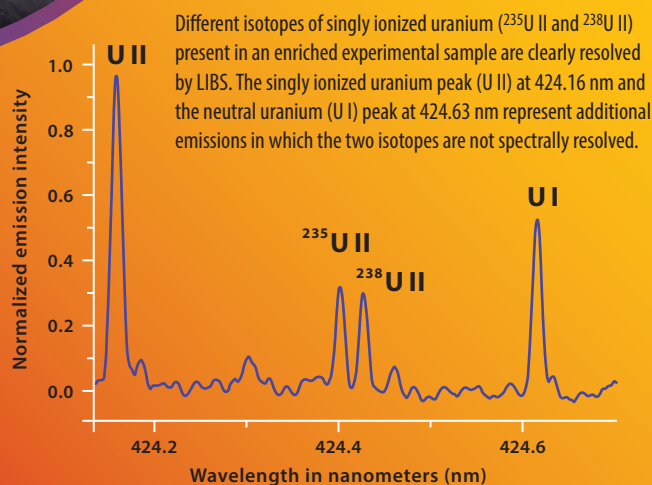


it can be used to determine the composition of enriched uranium oxide samples. It could also be used, if needed, to safely acquire reliable field measurements of debris, following a nuclear event. Some nonnuclear weapons, such as chemical or bioweapons, or even explosives, are also subject to LIBS-based detection and identification.

Another security-related application of LIBS comes from the oil industry. Loss of infrastructure, loss of productivity, and even loss of life have occurred in the past when refinery pipes suddenly failed, causing explosions. The steel used to make refinery pipes, which carry corrosive chemicals, needs a minimum concentration of silicon in order to resist corrosion. A backpack-mounted LIBS system called PipeLIBS, developed by Los Alamos scientists James Barefield and Elizabeth Judge, is now being deployed in refineries. It will be used to examine pipes prior to installation and also to inspect existing pipes and identify risks. The walls of refinery pipes carrying corrosive liquids are allowed to be no thinner than one-eighth of an inch. Yet Barefield and Judge have discovered corrosion-prone pipes in service that may have been much thinner than that. PipeLIBS is the only way to check pipes that are already in use because conventional chemical analysis requires cutting a hole in the pipe, which defeats the purpose entirely.

In agriculture, food- and water-security scientists are also looking at, and looking with, LIBS. Soil concentrations of essential elements like carbon, nitrogen, potassium, and phosphorus are easily measured with LIBS. Nitrogen-containing fertilizers are liberally applied to crop fields, often in extreme overabundance. The plants only take up so much, and the rest ends up contaminating the water table. Judge and Barefield, along with collaborators, are using LIBS to investigate solutions for this nitrogen overdosing: precision agriculture and sustainable agriculture.

James Barefield and Elizabeth Judge use their patent-pending, backpack-mounted PipeLIBS system to evaluate the safety of oil-refinery pipes.



History of LIBS at Los Alamos Scientists at Los Alamos developed LIBS for watershed preservation; however, the tool has become universally useful. A Los Alamos LIBS instrument is already exploring Mars and may one day explore Venus. National security, including weapons, energy, and food security, is improved by this adaptable, portable, and affordable tool.

Precision agriculture uses LIBS to measure the carbon, nitrogen, potassium, and phosphorus in soil. The idea is to use these data to ensure application of only the precise amount of fertilizer that will equal the plants' uptake. At present, the soil LIBS system is backpack-based, like PipeLIBS, but the goal is to have a LIBS system mounted on the front of a tractor. The soil's nutrients will be measured as the tractor travels, and a dispenser on the back will distribute the precise amount of each element to bring the whole field to uniform, ideal growing conditions.

Sustainable agriculture uses organic material to build up, or biomodify, the soil over several years to achieve optimal levels of these nutrients, guided by LIBS data. The result is a fertilizer-free field that uses much less water, produces higher yields, does not contaminate the water table, and is entirely self-sustaining.

From rocks on Mars to fields on Earth, LIBS is helping scientists do their jobs with improved speed, safety, and precision. And all of that is just at Los Alamos, where LIBS was pioneered. Scientists around the world are using LIBS for environmental assessment, cultural-heritage preservation, green-energy applications, and even crime-scene forensics.

Not bad for a little small-town laser. **LDRD**

—Eleanor Hutterer